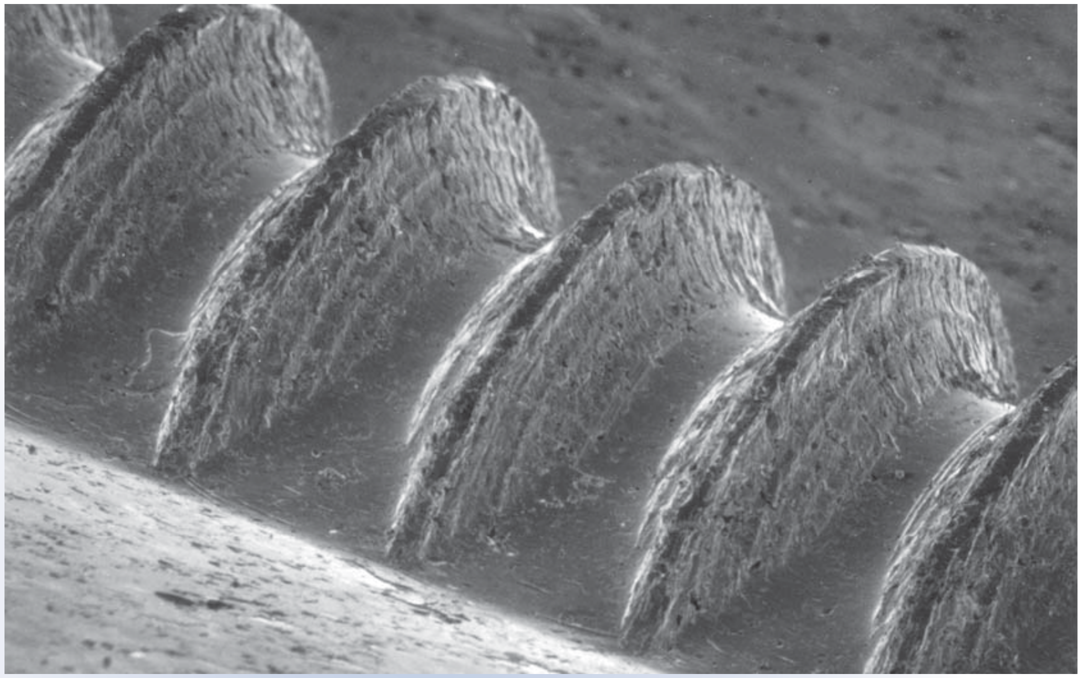
MEMS Fabrication by Spray Forming



INL's process was used to duplicate a machined tiny screw with amazing results. Scanning electron microscope photographs show the replication in metal of the image of a 90 threads/inch threaded rod that was left on a PMMA surface.

The field of micro-electro-mechanical systems (MEMS) is a rapidly growing multidisciplinary research area. A long-term goal of this research is to merge micro-systems of electrical, mechanical, and magnetic components into low-cost, highly-sophisticated control systems. Ultimately, it is believed that "smart" structures, such as embedded sensors, actuators, and control mechanisms, will be fully integrated into a structure, giving it the ability to sense stimuli and to take an appropriate response in a predetermined and controllable fashion. Many of the potential applications of these systems in health care, biotechnology, industrial automation, automotive systems and many consumer products depend on the availability of a materials processing technology that will enable microminiature parts to be produced from hard magnetic and other specialty alloys at low cost and at high production rates. Until now, such material processing technology was unavailable. The Idaho National Laboratory (INL) has developed a process that allows for low cost and high production of MEMS devices using practically any type of metal.

Microstructures, such as miniature gears, turbines, actuators, and filters (or microstructures) are produced with overall dimensions of about 10 to 500 µm. Currently, such devices are made by deep etch lithography combed with electroforming. MEMS production using etching or electroforming methods, however, places limitations on material choices and fabrication rates.

Researchers at INL have discovered a novel process for producing MEMS by spray forming. In INL's approach, atomized metal droplets were rapidly quenched in-flight and deposited onto micropat-

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terned polymers to produce complementary microstructures in metal. One benefit of this approach is that it is applicable to most metals of interest to this field, including hard magnetic alloys. Another benefit is that thin (~75 µm) films can be deposited onto micropatterned polymers at high rates using de Laval nozzles designed to produce wide spray patterns.

With tin, melt temperatures of 400°C and atomizing gas temperatures of 300°C have yielded good results with all substrate materials tested. Replication of fine detail on surfaces has been excellent.

For example, the image of a fingerprint that was left on a poly(methyl)methacrylate surface was clearly reproduced in a spray-formed metal deposit. Likewise, the image of a 64 µm diameter wire mesh in poly(methyl)methacrylate was reproduced by spray forming tin onto the micropatterned polymer.

At low metal throughputs (< 100 lb/h), similar results were obtained with the zinc-base alloy superheated to 600°C and atomized with argon or nitrogen heated to as high as 630°C.

General purpose polymers gave good results despite maximum continuous use temperatures that typically do not exceed about 80°C. At low metal throughput, the microstructure of sprayed deposits was not particularly sensitive to substrate material, finish and conformality were. Peak-to-valley surface roughness, measured with a stylus profilometer, were about 4 microinches (0.1 micrometers).

For a given metal, the order of these rankings depended on experimental conditions, but the order was reproducible for a given set of conditions.

The image of a fingerprint that was left on a PMMA surface was clearly reproduced in a spray-formed metal deposit.

Benefits of INL's Spray Forming MEMS Process

- Allows microminiature parts to be produced from hard magnetic alloys (including specialty alloys).
- Allows for easy production of MEMS in mass quantities.
- Provides a low-cost process fabrication method.
- Allows for reproducible process fabrication, thus minimizing the time necessary to produce additional MEMS devices.
- Provides a low cost production process at high production rates.

Partnering with INL

INL's goal is to find a party interested in developing and perfecting a manufacturing process for spray forming MEMS devices. INL has several patents on the general process, and the INL is interested in licensing these patents for MEMS manufacturing as well. See U.S. Patent Nos. 5,718,863 and 5,252,212. The process is already being commercialized for the rapid creating molds and dies.

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